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PYROPHORIC-COATED FLECHETTE STUDY

ORDNANCE RESEARCH INCORPORATED

TECHNICAL REPORT AFATL-TR-72-67

MARCH 1972

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EGLIN AIR FORCE BASE, FLORIDA

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FOREWORD

This report was prepared by Ordnance Research Incorporated, P. O. Box 1426, Fort Walton Beach, Florida 32548, under Contract No. F08635-71-C-0108 with the Air Force Armament Laboratory, Eglin Air Force Base, Florida. Mr. John J. Howanick (DLDG) monitored the program for the Armament Laboratory. Dr. Hal Waite was the principal investigator for the contractor, and Mr. T. B. Gortemoller was the program manager for the contractor. This report covers the period from 24 May 1971 to 31 January 1972.

The data presented in this report are the result of the combined efforts of several personnel. The efforts of Mr. Roscoe Walters and Mr. Jim Ford of Ordnance Research Incorporated were especially noteworthy.

This technical report has been reviewed and is approved.

For LEMUEL D. HORTON, Colonel, USAF
Chief, Guns and Rockets Division

ABSTRACT

The objective was to determine the feasibility of improving the performance of the 60-grain steel (SAE 1066) antimateriel flechette by adding an incendiary capability. The incendiary capability should be inexpensive and must not degrade the ballistic characteristics of the flechette. The approach taken was to coat the flechettes with a thin layer of friction-activated pyrophoric metals which were selected based on an analysis of their physical and thermochemical properties and of the terminal effects of the materials when gun launched. The results of this effort demonstrate that flechettes can be coated with a friction-activated pyrophoric coating which can reliably initiate a self-sustaining gasoline fire in either truck tankage or POL drums and that technique suitable for mass production is possible.

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SECTION I

INTRODUCTION AND SUMMARY

The use of pyrophoric metals to augment the terminal effectiveness of kinetic energy penetrators has received wide attention over the past few years. The major portion of this work has been done on a cut-and-try approach, using a favored material as a penetrator rather than an orderly program of the most cost-effective methods based on experience and knowledge of the entire range of pyrophoric materials.

The approach taken in this effort was to coat standard 60-grain steel flechettes with a thin layer of friction-activated pyrophoric material. Candidate materials were selected based on thermochemical and physical properties as related to the terminal ballistics of the flechettes and fabrication techniques.

Based on the relatively low terminal velocity of the flechettes (less than 1500 fps), mixed rare earths (MRE) and alloys thereof appeared to be the most promising pyrophoric metals for coating.

The initial process investigated for applying MRE to the flechettes was dip coating. For this purpose, eutectic or near eutectic alloys were used to minimize the temperature range over which the liquidus-solidus phase transition took place and thus control grain size. Three dip-coating techniques were used:

(1) Vacuum dipping.
(2) Dipping in an argon atmosphere.
(3) Dipping through a protective flux of sodium chloride.

Of these techniques, the last method produced the best quality coating.

The dip-coating process would be difficult to adapt to mass production even though an incendiary capability can be provided by this method. The coatings obtained through this process were not constant over the length coated, and evidence of dissolution of the steel during immersion in the MRE alloy resulted in loss of flechette mass. These factors will adversely affect flight stability and terminal ballistics. An improved coating process suitable for mass production was investigated, the results of which are shown in Figure 1. This process enables deposition of a uniform coating of controlled thickness and eliminates the dissolution of the steel and oxidation and scaling of the coating.

Testing during this effort was focused on typical targets that might be attacked by 2.75-inch FFAR with flechette warheads. The two targets tested (both simulated) were a POL drum and truck gas tank. Flechettes were gun-launched from a barreled Mauser bolt action chambered for caliber .458 Winchester. Cartridges were handloaded to achieve the required test velocities.

Velocities were recorded by the breakwire/velocity screen method with analysis of the fire-starting capabilities facilitated by high speed motion picture coverage.

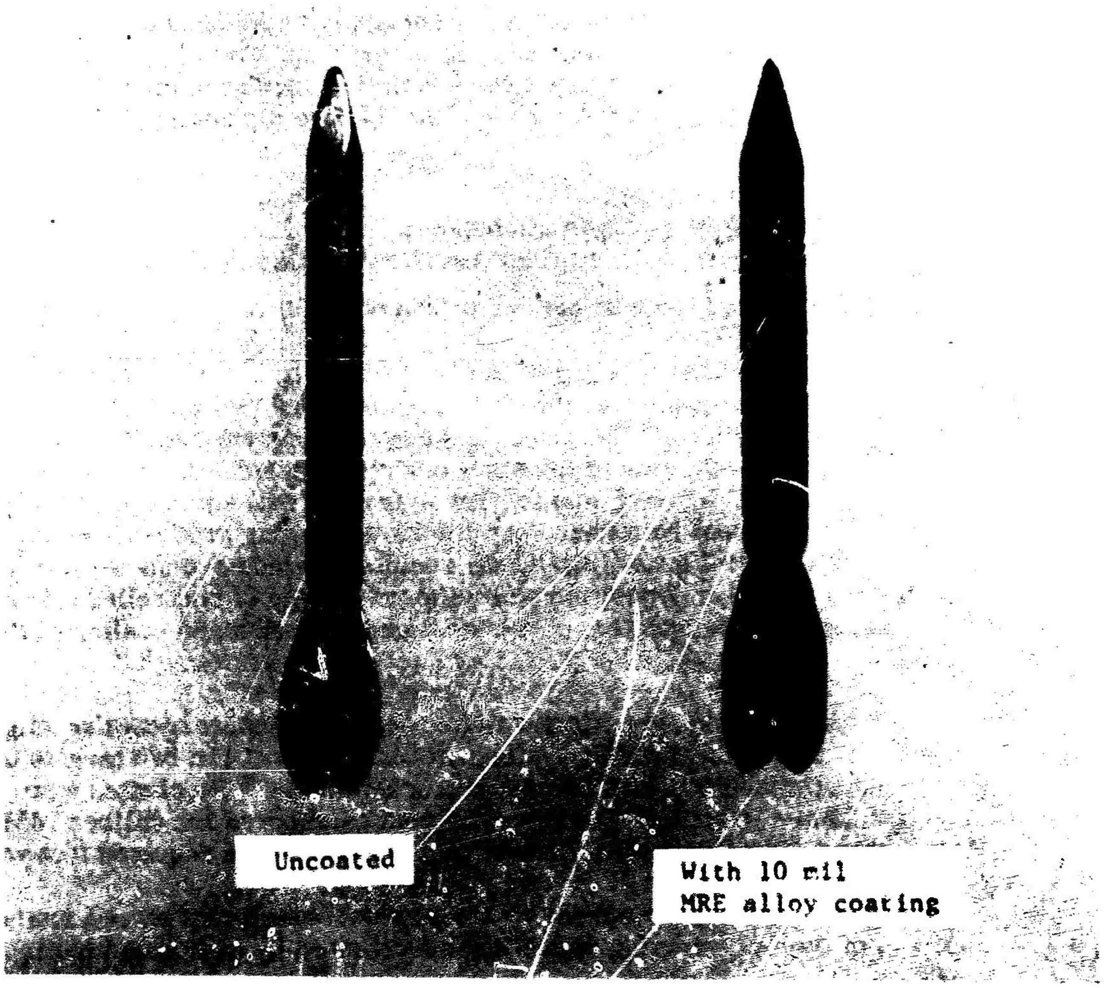

Figure 1. Dip-Coated Flechettes (Contractor Process)

The results of this effort demonstrated that the terminal effectiveness of the 60-grain antimateriel flechette can be improved by coating with a friction-activated pyrophoric metal coating and that a process suitable for mass production appears feasible.

SECTION II

TECHNICAL DISCUSSION

MATERIALS

Pyrophoric metal fragments have found recent application as kinetic energy penetrators for explosive and gun-launched munitions. The incendiary effects of pyrophoric metals offer certain advantages in the defeat of vehicle targets and in the venting and ignition of drummed POL. Previous developments have been based on the use of pyrophoric metal powders as fuels for exothermic pyrotechnic compositions (powdered fuel with oxidizers) for primary incendiary effect. The critical period for ignition of diesel fuel and, to a lesser extent, gasoline is the 10-to 100-millisecond period following fragment or penetration impact. Hydrostatic shock of the fuel body ejects a rapidly expanding vapor or fuel droplet cloud. The fuel-air mixture within the flammable limits forms and dissipates within a period of 10 to 200 milliseconds. Subsequent to this time interval only pooled fuel is available for ignition, requiring a high-temperature extended-burning ignition source. Most reliable ignition of volatile fuels will therefore occur when the fragmentation and incendiary capabilities are incorporated in a single munition, such as a friction-initiated pyrophoric coating for antimateriel flechettes.

Ordnance Research Incorporated, under Contract F08635-71-C-0020 with the Air Force Armament Laboratory, has been conducting a research and development program on pyrophoric metal penetrators. The objective of this program is to develop quantitative data which are descriptive of the terminal effects of state-of-the-art reactive metal penetrators impacting on single and multiple plates. The pyrophoric materials being evaluated include rare earth alloys, zirconium, zirconium-tin, depleted uranium, titanium, and Methonalloy®. The experimental tests that were performed utilized one-quarter-inch diameter by one-quarter-inch length test samples fired from a Mauser bolt action and caliber .30-.06 smooth bore barrel into simulated POL targets. The cartridge cases were handloaded to achieve the desired velocities of 1000 to 6000 feet per second. In addition, mechanical and thermochemical data of the metals were obtained.

The results of this program demonstrate that mixed rare earth alloys will more consistently initiate self-sustaining fire and perform well at significantly lower impact velocities than the other materials tested. Based on the relatively low terminal velocity of the flechettes (less than 1500 fps), mixed rare earths and alloys thereof appeared to be the most promising pyrophoric materials for coating.

This improved performance of the mixed rare earth alloys can be attributed to lower autoignition temperatures and the greater persistency of the particles ignited and dispersed upon impact with a hard target. This performance characteristic may be attributed to the presence of the second intermetallic phase in the solid solution of the mixed rare earths. This second phase increases frictional pyrophoricity and brittle fracture on shear stress (impact with the target) by internal friction on movement between phases. Elements such as zirconium fail in a ductile mode, and the pyrophoric effect is limited to the metal surface in frictional contact during penetration of the target. Internal molecular stresses and frictional forces are not present.

Mixed rare earths is a commercially available alloy (also known as mischmetal) which consists of about 50 percent cerium, the balance being a mixture of other rare earths of the cerium group of the lanthanides. The exact percentages depend on the source ore and refining and recovery processes. In general, the composition of MRE falls within the following proportions:

Cerium	48-52 percent
Lanthanum	23-27 percent
Neodymium	15-17 percent
Praseodymium	5-7 percent
Other Rare Earths	1-3 percent

The coating materials investigated during this program were:

90-95% cerium-enriched mixed rare earths
Mixed rare earths + 9% magnesium
Mixed rare earths + 14% copper
Mixed rare earths + 9% nickel
Mixed rare earths + 4% aluminum
Mixed rare earths + 13% zinc

The following paragraphs describe the coating process, test setup, and target rationale used during this program.

FLECHETTE COATING

Flechettes were dip-coated in eutectic or near-eutectic rare earth alloys by three techniques:

1. Initial trials were conducted in a small vacuum furnace with two near-eutectic rare earth alloys. These alloys were a 9% magnesium alloy and a 13% zinc alloy. The experimental setup is shown in Figure 2. The method of dipping the flechettes was as follows: the rare earth and alloy element addition were loaded into the graphite crucible, and the vacuum chamber was sealed. The furnace was then evacuated, back-filled with argon, and power applied to the graphite heater. When the alloy was molten, a positive pressure of argon was maintained to minimize dross formation while the top of the furnace was removed. Two or three flechettes were loaded into the holding fixture, and the vacuum furnace was resealed. The furnace was then evacuated, and the flechettes were dipped for a prescribed period of time. After dipping, the furnace was again back-filled with argon and the coated flechettes were removed from the furnace and holder.

2. Dipping flechettes under a protective argon blanket was conducted in the following manner. The rare earth alloy was melted in a clay-graphite crucible in a gas-fired furnace, and an argon atmosphere was maintained at all times. Individual flechettes were dipped for a prescribed time into the molten rare earth alloy after any slag present on the surface had been skimmed aside. It was then rapidly transferred to a quenching bath of water to prevent oxidation of the coating. In some tests, the flechette was preheated before dipping.

3. The following procedure was employed when flechettes were dipped through a flux cover. The rare earth alloy was melted in an induction furnace

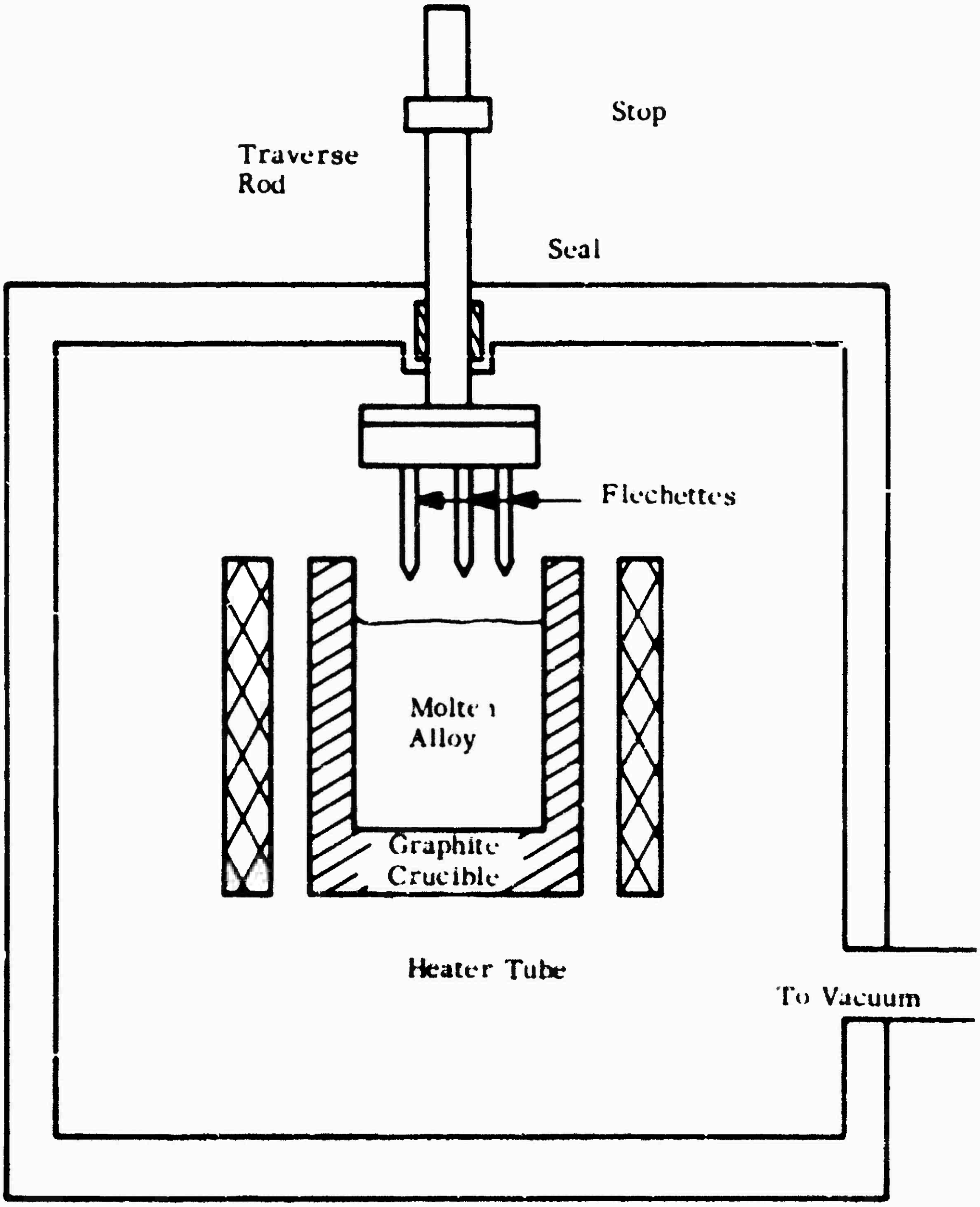

Figure 2. Arrangement for Dip-Coating Flechettes in Vacuum

in a clay-graphite crucible under an argon blanket. When the alloy was completely molten, the sodium chloride flux was applied to the surface and the argon blanket was removed. The sodium chloride flux became molten and then formed a protective barrier against the outside atmosphere. The flux was cleared from a small area in the center of the crucible, and the flechette was dipped into this region. The flechette was quenched in water after dipping to protect the coating from oxidation. Of the three techniques, this method with the sodium chloride flux produced the best quality coating.

Some experimentation was conducted to determine the time required for producing the required coating thickness. Dipping times ranged from 3 to 8 seconds in the vacuum furnace and from 5 to 10 seconds when plunging under argon and a flux. It is estimated that metal temperatures were in the region of 100 to 200°F above the liquidus for each alloy when coating tests were conducted.

Dipping flechettes into 9% magnesium and 13% zinc rare earth alloys held under vacuum produced a poor quality coating. There were two reasons for this result:

(1) There was a large amount of slag formed on top of the molten metal bath which prevented the flechette from entering and leaving the molten pool in uniformly wetted condition. This slag was identified as cerium oxide and cerium carbide. Oxygen contamination in the vacuum furnace during loading of the flechettes was unavoidable. The cerium reacted with the graphite crucible to form cerium carbide; this did not occur with the clay-bonded graphite crucible.

(2) Evaporation of magnesium and zinc occurred in a vacuum. The effect of this evaporation was to cover the inside of the furnace with magnesium or zinc and also coat the surface of the flechette before dipping. This coating had a poor bond to the flechette and could easily be removed. Upon dipping, therefore, any material accumulating on the flechette would not bond to it. Because of these difficulties, the experiments in the vacuum furnace were suspended.

The work then concentrated on dipping the flechettes into a molten bath under an argon shield in atmospheric conditions. These experiments were initially conducted with a 13% zinc alloy. Best results were obtained by dipping cold flechettes into the metal bath and pulling them straight out after a prescribed time. The coatings were rough in appearance, and in some instances the coating bonded poorly to the flechette; the bond between coating and flechette was mainly mechanical in character. In this experiment, the surface of the rare earth bath was contaminated with oxide slag despite skimming before the flechette was dipped. Similar tests were conducted with a 9% nickel alloy and then 90-95% cerium. The results obtained in these tests were very similar to those produced with the 13% zinc alloy. Poor performance was attributed to oxide contamination of the molten bath surface.

Final dip coatings were conducted with the sodium chloride flux on an induction-melted bath with two alloys. These were 4% aluminum alloy and a 14% copper alloy. Melts were prepared under argon and then covered with a sodium chloride flux. The flux became molten on the bath and provided a clean metal surface. In time, the flux became crusty and had to be broken where the flechette was to be dipped. The surface quality of the dipped flechettes was much improved. The surface finish was relatively smooth, although the diameter of the coated flechettes was not constant over the length of the flechette. This was the most satisfactory of the three dipping methods. Figure 3 shows typical dip-coated flechettes.

Where the flechette had been dipped too deeply and the rare earth coating extended onto the fins, this excess material was broken off. The interface surface of the coating thus exposed (indicated) that there had been a metallurgical bond between the flechette and the coating. The interface showed crystalline structure and was quite bright. On measuring selected flechettes, it was found that the change in diameter with the coating was quite small and was, in some cases, a decrease. It was concluded that the steel was dissolved to some extent by the molten rare earth, and the final diameter of the flechette with a coating reflects the balance between the rate of flechette substrate dissolution and the rate of coating buildup.

The dipping dwell time in these experiments was approximately five seconds. Longer periods of time did not improve the coating quality and could cause a further reduction in the flechette-coated diameter. This was the result of increased dissolution of the flechette base material combined with its increasing temperature. The result of this is a reduction in the heat transfer and solidification of the rare earth coating. Ultimately the coating will remelt.

None of the dip-coating processes appears to be suitable for mass production without additional process development; however, flechettes coated in this manner demonstrate an incendiary effect capable of reliably initiating a self-sustaining fire against simulated truck fuel targets. A process suitable for mass production was investigated independently by the contractor, and items so coated demonstrated similar fire-starting capability. Improved incendiary performance can be expected from items coated with the improved process which allows close control of the coating thickness and minimizes oxidation of the coating and formation of scale. The bonding of the coating to the flechette is superior and by the proper choice of coating compositions can result in the formation of an intermetallic bond.

TEST SETUP

The coated flechettes were gun-launched from a smooth-bore .458 barrel provided with a Mauser bolt action. The cartridge cases were handloaded to achieve the desired test velocity. A discarding nylon sabot, as shown in Figure 4, was used during these tests. The basic test setup is shown in Figure 5.

Flechette velocities were determined by the breakwire velocity screen method by breaking a circuit and at some accurately measured distance (8.175 feet in these tests) further down the flight path, the projectile breaks a second circuit. A schematic of this system is shown in Figure 6. The breakwire is ruptured by the passage of the flechette as it leaves the barrel. The second circuit is interrupted by the projectile passing through a screen that consists of a fine line of conductive material bonded to a thin paper structure. Breaking of the circuits discharges a capacitor which triggers a counter at the breakwire and stops the counter at the velocity screen, thus providing the time to travel a known distance. Measurements taken by this method demonstrate average velocity accuracy within 2 percent; however, test velocities were reported to the nearest ten feet per second.

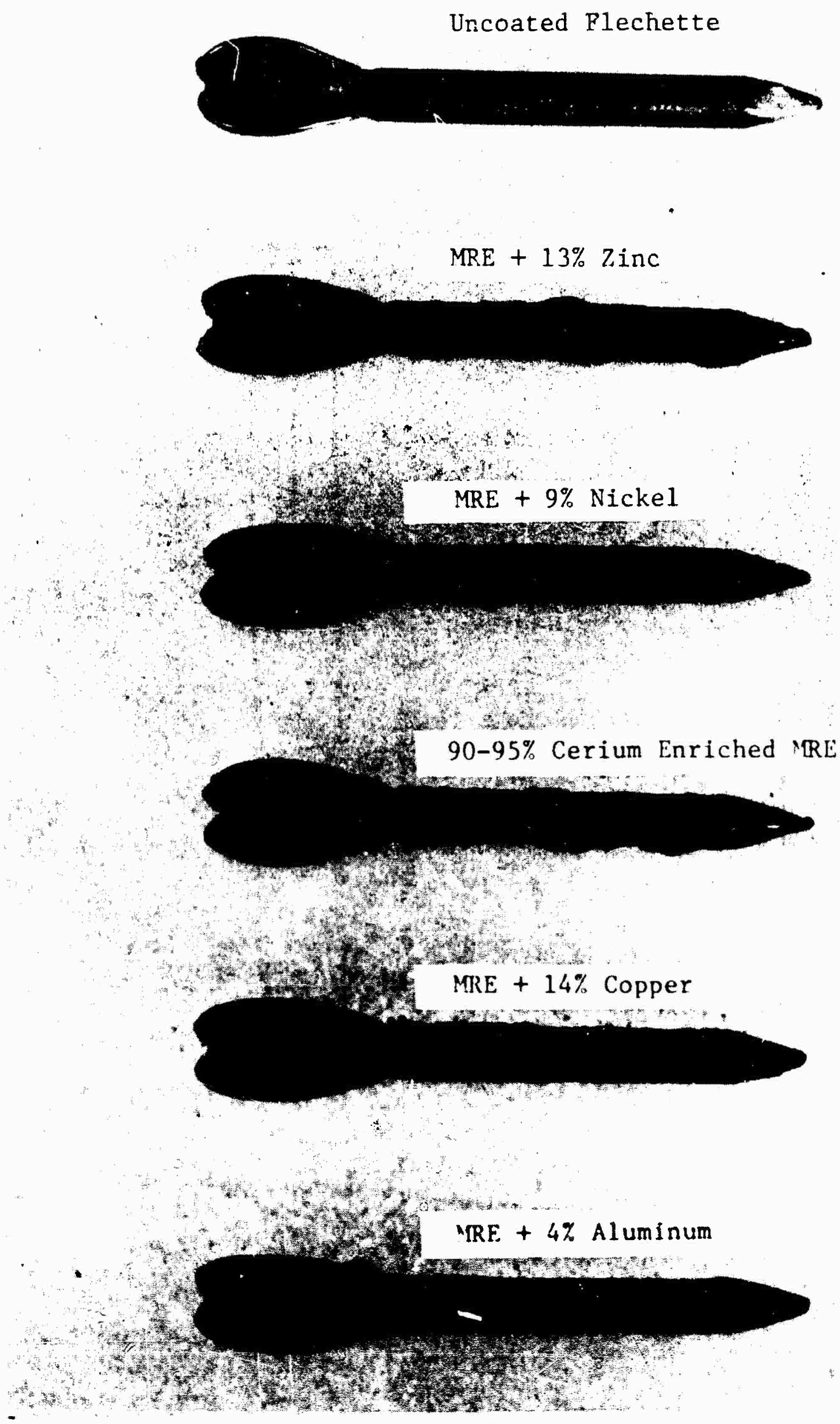

Figure 3. Uncoated Flechette with Examples of Flechettes Dip-Coated with Various Pyrophoric Metal Compositions

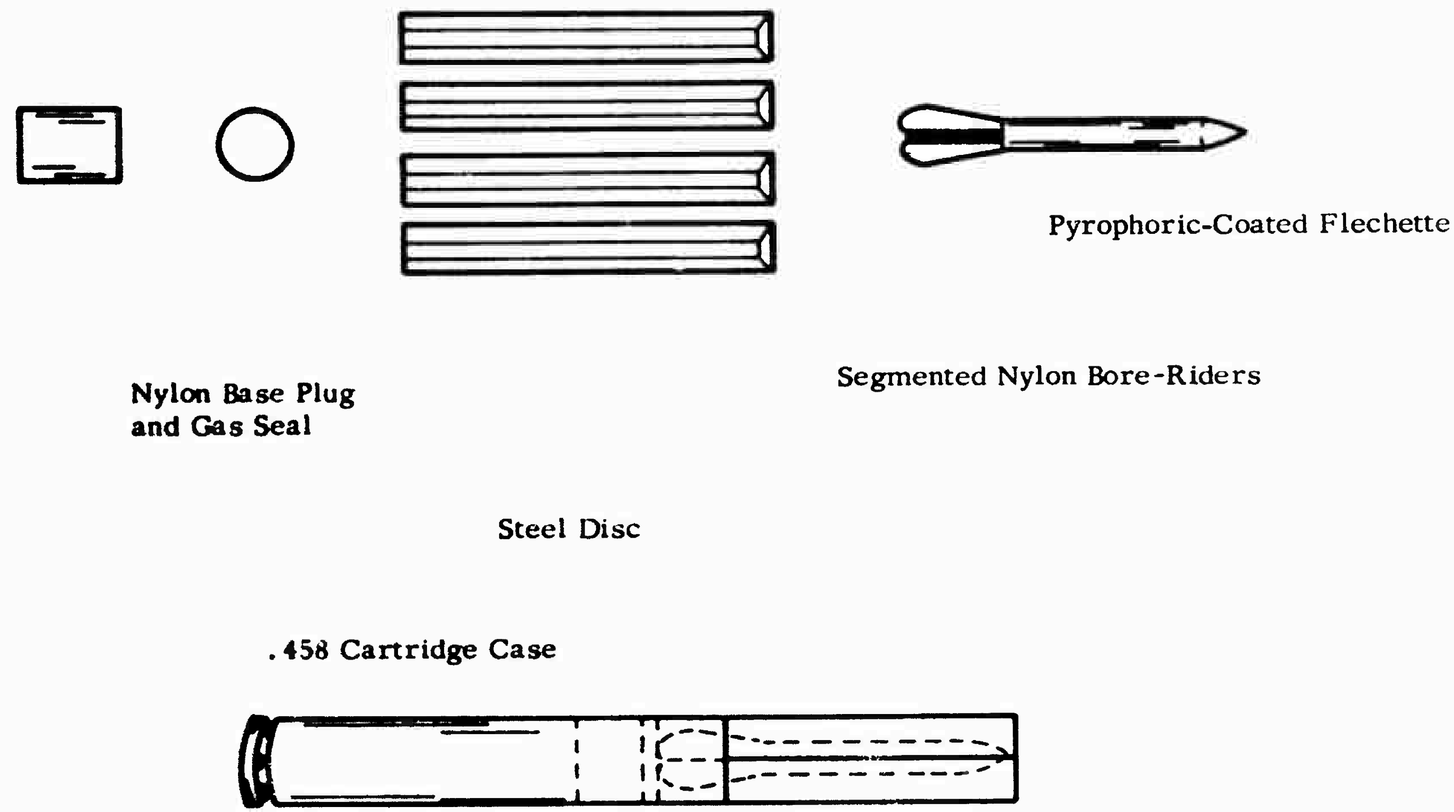

Figure 4. Sabot for Gun Launch of Pyrophoric-Coated Flechettes

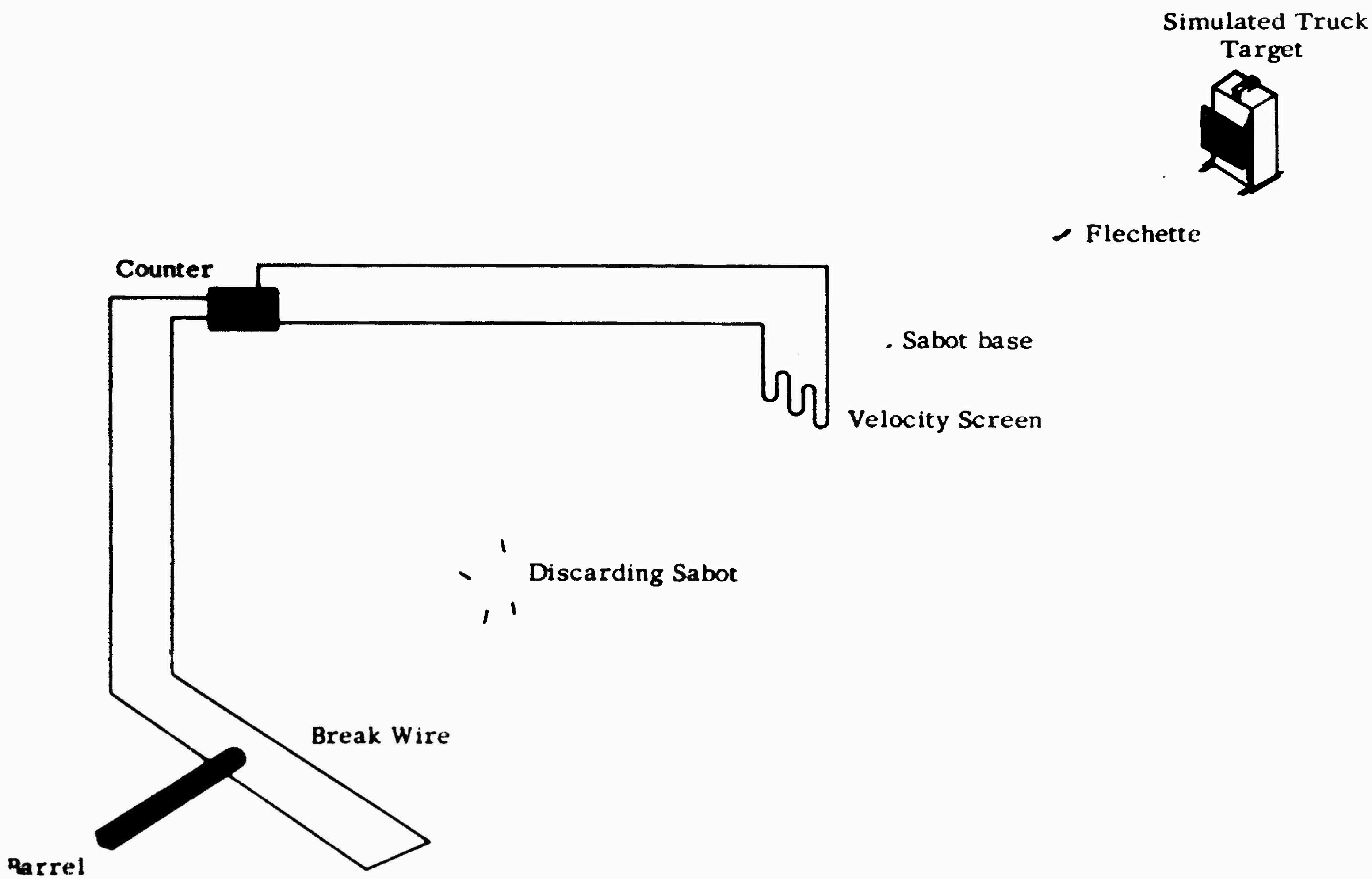

Figure 5. Schematic of Test Setup

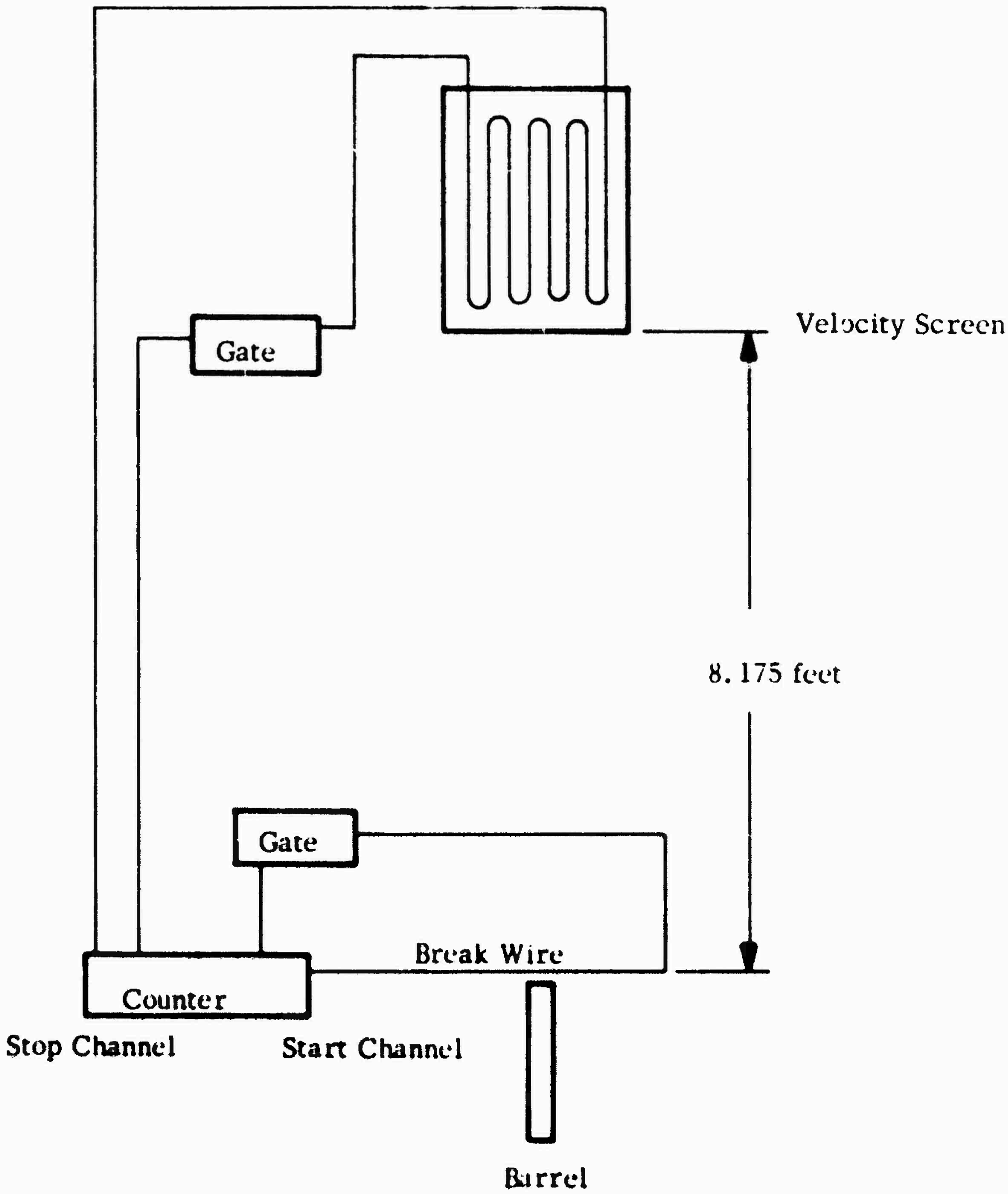

Figure 6. Velocity Measurement Schematic

In selecting a representative target, it is important to understand the mechanisms for fuel fire and/or explosion initiation due to impacts by incendiary-augmented kinetic energy penetrators such as the pyrophoric-coated flechette. Penetration of the projectile into the liquid space of the fuel tank provides a means for the formation of a fuel-air cloud which can be ignited by the dispersed incendiary particles if certain criteria (which are discussed below) exist. If not directly ignited by the initial penetrator, the leaking fuel can subsequently be ignited by other projectile impacts nearby. Projectile impacts into the ullage of fuel tanks provides another means of initiation of a self-sustaining fire of less intensity.

Early experiments concerning fuel ignition by incendiary-bullet penetration and similar experimentation with Fastax camera coverage resulted in the postulation that the following conditions are essential to successful ignition of a fuel target.[1]

1. Penetration of the fuel cell by a projectile.
2. Emergence of the fuel from the fuel cell.
3. Mixture (however incomplete) of fuel and air in combustible proportions.
4. Existence of an adequate igniter in the zone of combustibility.

The mechanism of hydrocarbon ignition and combustion has been analyzed extensively over the past few years. During the latter part of World War II, British scientists studied the mechanisms involved in the release of fuel from aircraft fuel tanks and the processes involved in diffusion and ignition of these fuels. In general, it was found that the relative volatility of a fuel is the most important single factor in the determination of the ignition and flame propagation qualities of a fuel spray. The probability of the incidence of propagated flame in fuel-air mixtures at temperatures below the flash-point is small unless the fuel is dispersed in a manner which favors aerosol formation.

It has been confirmed experimentally that a condition of flammability exists in a fuel-air system when the temperature, which controls the equilibrium concentration of the fuel-vapor and air mixture, lies between certain limits known as the upper and lower limits of flammability. With a typical gasoline, this zone of flammability occurs at fuel temperatures between 100 to 110°F at sea level. Within the above flammability zones, a fire or explosion can result from contact with an ignition source. The flash point of a given fuel is defined as the lower limit of the flammability zone.

The lower and upper limits of flammability indicate the percentage of combustible gas in air below which and above which flame will not propagate. When flame is initiated in mixtures having compositions within these limits, it will propagate and therefore the mixtures are flammable.

It is generally postulated that combustion of hydrocarbons (1) occurs in the vapor phase, (2) is a chain reaction dependent upon the formation of unstable species such as free atoms and free radicals, and (3) can occur only within certain well-defined limits of concentration. To ignite a system of air and

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[1]G.H. Custard, G. Francis, and W. Schnackenberg, Small Arms Incendiary Ammunition, A Review of the History and Development, AD 159323, II, p 152.

liquid hydrocarbon fuel, therefore, enough energy must be provided to establish the above conditions at some point in the system. Flame will not be propagated, however, if the energy released following ignition is not great enough to spread the required conditions to adjacent areas or if too much energy is lost to the surroundings.

Theoretical consideration of the incendiary burst has been approached from several standpoints. Fundamentally, the burst produced by the incendiary is nothing more than a source of ignition for fuel fires. In itself, it is incapable of directly destroying a target because it is unlikely that an incendiary burst of sufficient intensity or duration to actually weaken structures can be produced by small incendiary-augmented kinetic energy penetrators. With reference to the incendiary burst as a source of ignition for fuel-air mixtures, the intensity, position, and duration of the burst determine the probability of the desired ignition. This assumes that an ignitable mixture exists somewhere within the immediate impact area.

The position of the burst is determined primarily by the sensitivity of the coating and its ability to carry through target areas to good depth. The physical size of an incendiary burst determines the effective radius. This phenomenon has been found important to the effectiveness of sparking-type incendiary compositions, because as they spread throughout a target area, many individual sparks tend to produce a very large volume of effective burst.

Various attempts have been made to determine the minimum ignition temperatures for various fuels. A popular experimental procedure for such determinations involves confinement of the fuel-vapor and air mixture in a suitable container and application of uniform external heat until the mixture ignites. There exists, however, an ignition lag which is dependent upon several variables.

Probably the most important factor in the ignition lag is the formation of a fuel-air cloud within the combustible limits that is in contact with an ignition source of sufficient strength to initiate a self-sustaining fire. These ignition delays for the simulated truck gas tank target were approximately 40 milliseconds.

The target configurations used during testing were selected to be representative of a typical target as it would be seen by the munition when delivered from an aircraft in a combat situation. Figures 7 and 8 show the simulated truck fuel tank target. Figure 9 shows the simulated POL drum target used. A more generalized drum target is depicted in Figure 10 which shows simulated stacked drums. Water is recommended in the two cans adjacent to the fuel test module for safety aspects to prevent a cook-off explosion of an unvented fuel container.

With single projectiles, the geometry of the target setup is important in providing a means to trap both the incendiary particles and the fuel in the target area to increase the probability of achieving conditions suitable for combustion. With multiple hits in the area, target geometry is not as critical a factor but should not be overlooked.

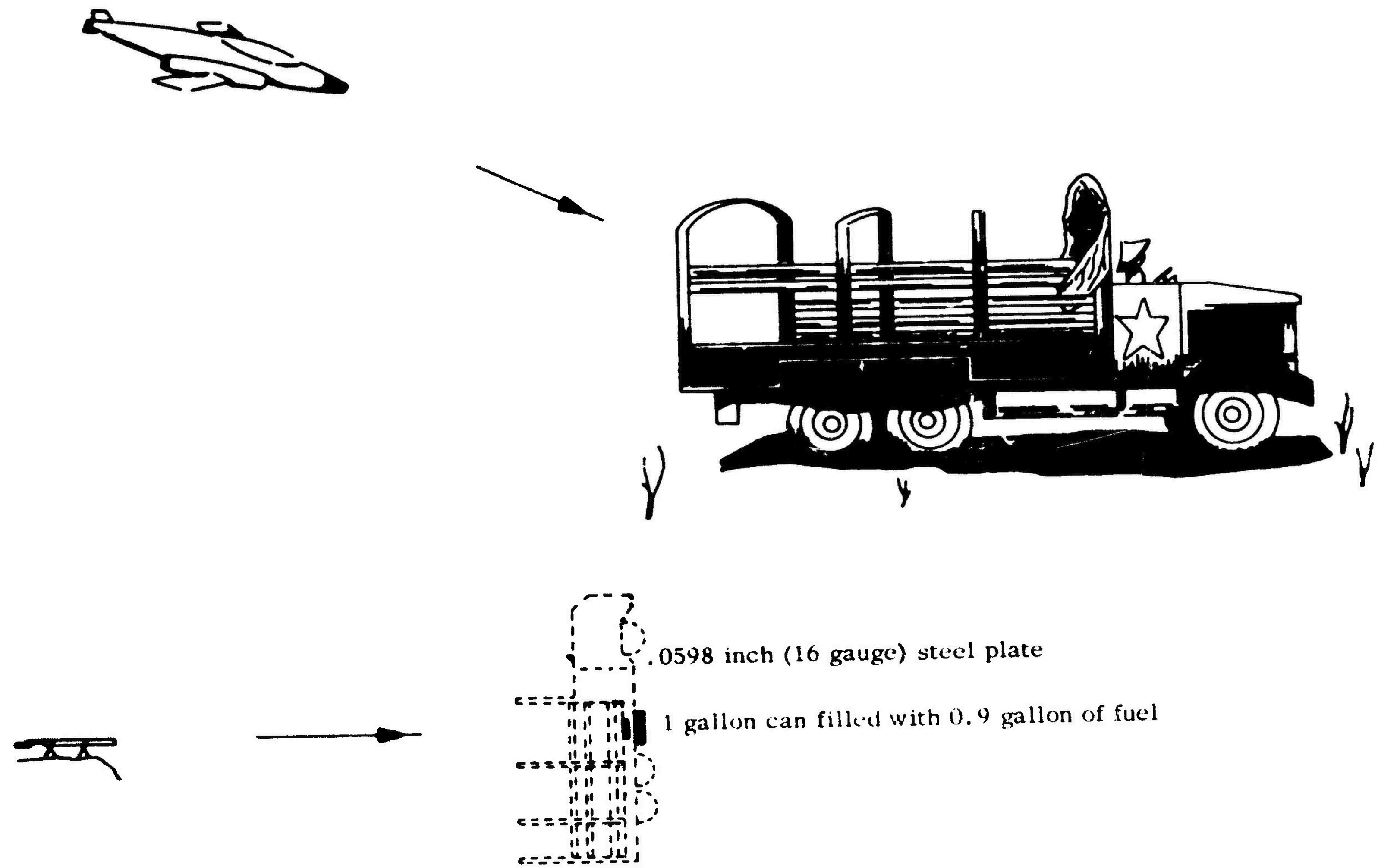

Figure 7. Real Target Compared to Simulated Truck Fuel Tank Target

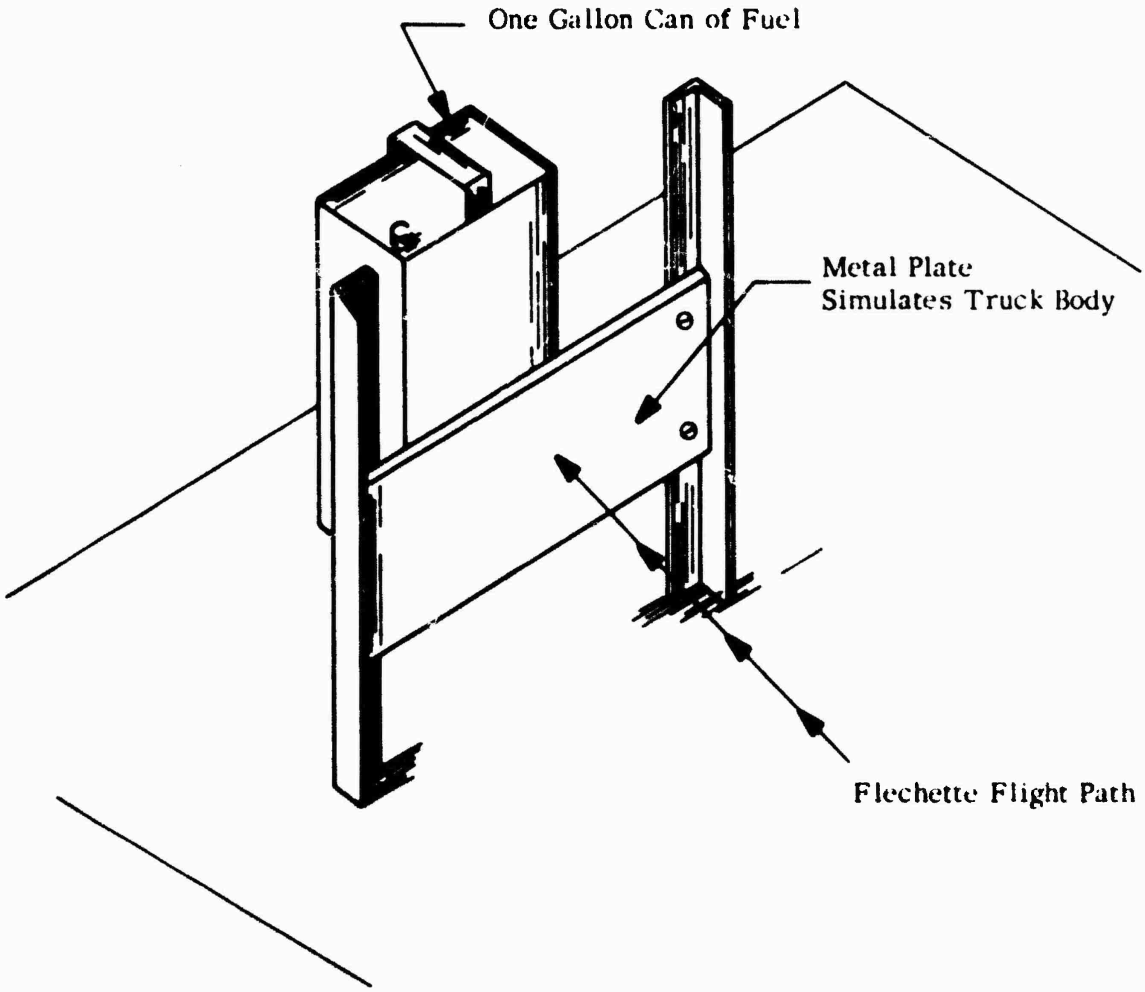

Figure 8. Simulated Truck Fuel Tank When Attacked From Above as Air-Delivered Rocket Attack

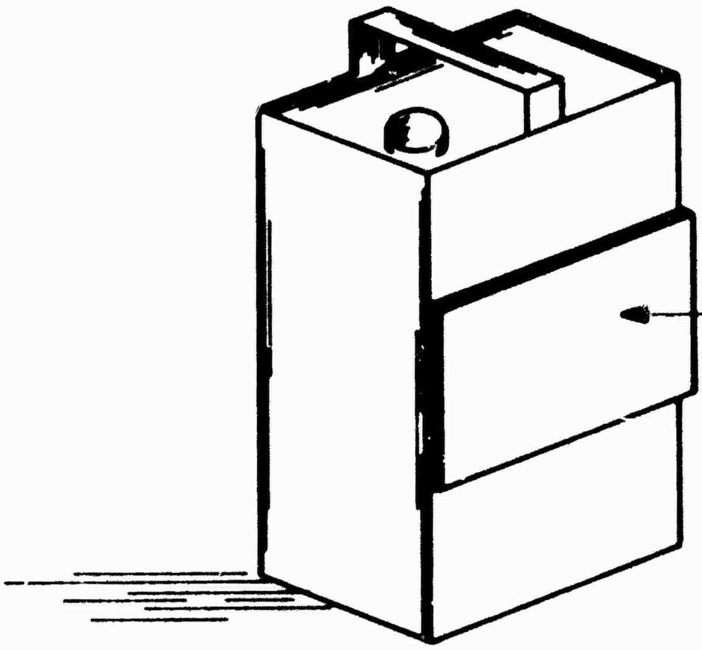

Figure 9. Simulated POL Drum

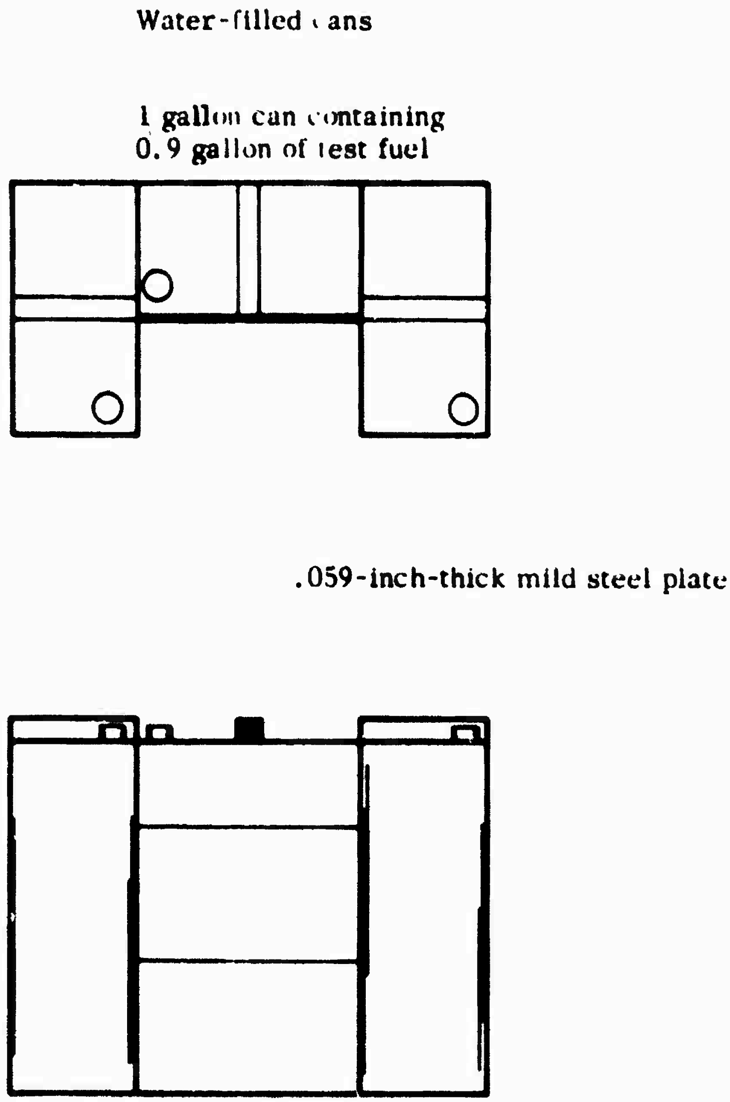

Figure 10. Simulated Stacked Drums

SECTION III

RESULTS AND CONCLUSIONS

The feasibility of increasing the terminal effectiveness of the 60-grain antimateriel flechette by providing an incendiary capability in the form of a friction-initiated pyrophoric coating has been demonstrated. In tests against a simulated truck gas tank, a single coated flechette was able to initiate a self-sustaining fire with a probability greater than .85. These results are summarized in Table I.

Table II summarizes the results of a single pyrophoric-coated flechette against a simulated fuel drum. The lower rate of initiation of a self-sustaining fire with a single drum target is expected because of the geometry of the target. A single fuel drum is a much more difficult target to ignite than a truck gas tank because of its smooth surfaces which do not provide stagnation areas. The irregularities of the truck body provide these stagnation areas which retain the dispersed ignition sources until the correct fuel-air mixture is obtained. Multiple hits will increase the performance against either target greatly.

Analysis of high-speed motion picture records indicated a delay of approximately 40 milliseconds between flechette impact and ignition of the resulting fuel-air cloud. The duration of the scintillating ignition sources of the flechettes coated with MRE + 4% aluminum was approximately 100 milliseconds, which is more than adequate for ignition of the fuel-air cloud.

The coatings obtained by the dip-coating processes were not constant over the length coated; also, there was evidence of oxidation and scaling of the pyrophoric coating. Based on flechette weight loss, some of the steel apparently dissolved in the rare earth alloy during immersion. The dip-coating process must be further developed to be feasible for production even though an incendiary capability can be provided through this method. An improved coating process suitable for mass production has been investigated by the contractor. Figure 1 shows the comparison of an uncoated item with a flechette coated by this process. A uniform coating of controlled thickness is possible by this technique; also, there was no evidence of weight loss or scaling of the coating as was the case with dip-coating methods.

The results of this effort demonstrated that a thin layer of friction-activated pyrophoric material will augment the fire-starting capability of steel penetrators. In addition, the results of tests under this and related research and development efforts indicate the following:

1. Initiation of fuel fires at lower impact velocities than those demonstrated can be achieved with an alternate MRE alloy coating.

2. MRE alloys are available that demonstrate acceptable corrosion resistance.

3. An economically feasible means of providing a controlled pyrophoric coating is possible.

4. The concept can readily be weaponized and will conform to military specifications for similar type munitions.

TABLE I. TEST RESULTS OF PYROPHORIC-COATED FLECHETTES AGAINST A SIMULATED TRUCK GAS TANK

Velocity (feet/second)	Pyrophoric Metal	Results
	90-95% Cerium enriched mixed rare earths	
2030		Sustained Fire
2080		Sustained Fire
2100		Sustained Fire
2130		Sustained Fire
2270		Sustained Fire
2310		Sustained Fire
2670		Sustained Fire
	86% MRE + 14% Copper	
1090		No Fire
	91% MRE + 9% Nickel	
2070		Sustained Fire
	96% MRE + 4% Aluminum	
660		No Fire
1060		Sustained Fire
1060		Sustained Fire
1090		Sustained Fire
1130		No Fire
2100		Sustained Fire

Note: The tests in which the flechettes did not penetrate either the target plate or can were considered as no tests.

TABLE II. SUMMARY OF TEST FIRING OF COATED FLECHETTES AGAINST SIMULATED DRUMMED MOGAS

(Sterile Target Configuration, No Confinement)

Mixed Rare Earth + 9% Nickel

Velocity	Results
904	Hit below liquid level - sustained fire
948	Hit below liquid level - no fire
954	Hit below liquid level - no fire
1002	Hit below liquid level - no fire
1030	Hit at liquid level - sustained fire
1068	Hit below liquid level - no fire
1074	Hit above liquid level - sustained fire
1078	Hit below liquid level - no fire
1764	Hit below liquid level - no fire
1961	Hit below liquid level - no fire
2038	Hit below liquid level - no fire
2309	Hit below liquid level - no fire
2593	Hit below liquid level - no fire

Mixed Rare Earth + 13% Zinc

Velocity	Results
968	Hit above liquid level - no fire
982	Hit above liquid level - sustained fire
989	Hit below liquid level - no fire
1004	Hit above liquid level - sustained fire
1107	Hit below liquid level - no fire
1134	Hit below liquid level - no fire
1154	Hit below liquid level - no fire
1636	Hit above liquid level - sustained fire

SECTION IV

RECOMMENDATIONS

The results of this and other related research and development programs indicate that the following should be pursued to insure that weapon development efforts fully utilize advancing technology:

1. Establish the optimum coating quantity and thickness and the performance specification and testing criteria for coating flechettes.

2. Load ten warheads with coated flechettes for USAF testing as follows:

   4 - For safety and environmental military standard testing

   6 - For target effectiveness

3. Determine the feasibility of providing an incendiary capability for fragmenting munitions, such as the BLU-61, BLU-63 and/or other munitions, for coating the external area of the fragmenting section with a friction-activated pyrophoric coating.

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USA ABERDEEN R&D CTR (AMXRD-BTL)	1
FRANKFORD ARS	1
PICATINNY ARS (SMUPA-RT-S)	1
USN WPNS LAB CODE TR	1
USN WEA CNTR (CODE 753)	2
57 FTR WPN WG (FWOA)	1
USAF TAC FTR WPNS CTR (CRCD)	1
DDC	2
CINCUSAFE (DMW)	1
CINCUSAFE (OA)	1
CINCPACAF (DMWXE)	4
HQ PACAF (IGY)	1
DL	1
DLD	1
DLOSL	2
DLDG	30

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13. ABSTRACT

The objective was to determine the feasibility of improving the performance of the 60-grain steel (SAE 1066) antimateriel flechette by adding an incendiary capability. The incendiary capability should be inexpensive and must not degrade the ballistic characteristics of the flechette. The approach taken was to coat the flechettes with a thin layer of friction-activated pyrophoric metals which were selected based on an analysis of their physical and thermochemical properties and of the terminal effects of the materials when gun launched. The results of this effort demonstrate that flechettes can be coated with a friction-activated pyrophoric coating which can reliably initiate a self-sustaining gasoline fire in either truck tankage or POL drums and that a technique suitable for mass production is possible.

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Friction-Activated Pyrophoric Coating						